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SEDIMENTATION OF LAKE BARCROFT FAIRFAX COUNTY, VA.

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SEDIMENTATION OF LAKE BARCROFT, FAIRFAX COUNTY, VA.

by John N. Holeman, Geologist, and A. F. Geiger, Geologist,
Soil Conservation Service[1]

Introduction

This report outlines the results of a sedimentation resurvey of Lake Barcroft, Fairfax County, Va., made by the Soil Conservation Service, United States Department of Agriculture. The survey was made as part of the summer program for geology student-trainees stationed at the Central Technical Unit, Beltsville, Md. It was carried out in August 1957.

The Problem

In recent years the general trend of suburban development has been of concern to agricultural people. Large acreages of crop and pasture land have been replaced by housing developments, shopping centers, streets, and roads. This results in the removal of productive land needed to produce food and fiber for an ever-increasing population.

Although the impact of "urbanization" will not be fully felt for another decade or two, there is an immediate effect which is readily apparent when large areas of watersheds are suddenly converted from agricultural to urban areas. The removal of protective vegetation by construction exposes the land to serious erosion, and the subsequent replacement of the surface of the land with roofs, streets, and parking lots, creates flash runoff. These processes result in increased downstream floodwater and sediment damages.

Although floodwater and sediment damages are mounting rapidly below urbanized areas, the trend to suburban development is so recent that little information has been obtained so far on what effects drastic land use changes in the watershed will have on downstream flow and sediment loads of streams.

Purpose of Survey

The Lake Barcroft sedimentation resurvey was made to: (1) Compare the sediment yield in 1957, after two-thirds of the watershed had been urbanized, with that 20 years earlier, when the watershed was predominantly in agricultural uses; (2) measure the loss of capacity of the lake due to this change in sediment yield; and (3) provide a basis for predicting the future life of the lake. Such information is needed in the United States Department of Agriculture's flood-prevention and watershed-protection work. Under the provisions of Public Law 566, the Department receives numerous applications from municipalities for Federal assistance in the development of work plans and in the construction of works of improvement to reduce floodwater and sedimentation damages. The results of the survey are intended to provide information useful for predicting and evaluating future sedimentation damages as a result of urbanization.

General Information

Location. --Lake Barcroft Dam is located just under 1 mile west of Bailey's Cross Roads, Fairfax County, Va. The dam is constructed across Holmes Run and impounds water in the valleys of Holmes Run and its tributary, Tripps Run, which unite one-fourth mile above the dam.

Purpose served and ownership. --Lake Barcroft was originally constructed in January 1915 by the Alexandria Water Company as a reserve water supply for the city of Alexandria, Va. Use as a water-supply reservoir was discontinued in 1950, and it was purchased by the Lake Barcroft Corporation for real-estate development. The lake now serves recreational and esthetic purposes for owners of homes in Lake Barcroft Shores development.

Description of dam. --The dam is concrete and masonry about 400 feet in length and 63 feet in maximum height above the stream bed. In July of 1942 the spillway section, in the center of the dam, was raised 5 feet by means of gates, increasing the spillway height to 62 feet above the stream bed. The spillway section has a total length of 200 feet; however, this includes the outlet tower giving a net length of only about 180 feet. The 1957 crest at the top of the 5-foot gates is 210 feet above mean sea level.

The reservoir. --Storage in Lake Barcroft began in January 1915. The length of the lake in the Holmes Run arm from the dam to the head of backwater is 1.4 miles. The Tripps Run arm is 0.7 mile long.

[1]The field party was under the direction of A. F. Geiger, geologist, assisted by J. N. Holeman, geologist, Central Technical Unit, Soil Conservation Service, Beltsville, Md. J. L. Hunt, geologist of the Maryland Watershed Planning Party, Beltsville, Md., provided equipment and technical assistance during the course of the survey.

Student-trainees participating were: William Collier, Robert F. Mikkelson, James T. Nacos, William R. Perkins, and Borys Bilokur.

Barcroft Beach, Inc., through Joseph V. Barger, granted permission for the survey and provided boats and motors for use of the field party. Permission was also provided for the operation of the outboard motors otherwise restricted to authorized personnel of the corporation.

The late Dr. Victor H. Jones reviewed the manuscript and offered many helpful suggestions.

The original area of the lake was 115.4 acres, and in 23 years to 1938 decreased only 0.4 acre. After the spillway was raised 5 feet in 1942, increasing the lake's maximum water-surface elevation to 210 feet above mean sea level, the area of the lake was expanded, primarily in the end segments, to about 135 acres. In the last 15 years the area has decreased at a faster rate mainly by the formation of deltas so that the 1957 surface of the lake as planimetered from aerial photographs is about 129 acres, reducing the area by about 6 acres from its greatest area after raising the spillway in 1942.

Area of lake at spillway level	Acres
Original (January 1915)	115.4
February 1938	115.0
July 1942	[1] 135
December 1953 (from planimetering aerial photos)	130
August 1957	129
Reduction by sedimentation (1942-57)	6

Storage capacity to spillway level	Acre-feet	Gallons
Original (January 1915)	1,847	601,844,950
February 1938	1,762	574,147,700
July 1942	[1] 2,380	[1] 775,523,000
August 1957	2,092	681,678,200

[1]Estimated on basis of rate of silting prevailing to 1938.

Method of Survey

1938 survey. --An initial sedimentation survey was made by the Soil Conservation Service from September 17, 1937, to March 8, 1938. The results of this survey, together with detailed information on the watershed are reported by Barnes.[2] The survey consisted of mapping the shoreline at crest elevation 205 m.s.l. A triangulation system of 52 stations was expanded from a 1,030-foot baseline extending along the east shore near the dam. This system was supplemented by 13 planetable stations for mapping shoreline and establishing cross-section ranges. The original map was prepared on a scale of 1 inch equals 200 feet.

Sediment and water-depth measurements were made at close intervals along 41 cross-section ranges (figs. 1, 2). Measurements of sediment thickness were made with 6- and 10-foot sampling spuds. All range ends and cut-in stations were permanently marked with standard Soil Conservation Service bronze tablets stamped with the station numbers and set in concrete bases.

1957 survey. --The fieldwork was based on the maps and ranges determined in the 1938 survey supplemented with aerial photographs made in 1937 and 1953. Where the concrete markers were found, a steel airplane cable was stretched

[2] Barnes, F. F. Advance Report on the Sedimentation Survey of Barcroft Reservoir, Alexandria, Virginia. U. S. Dept. Agr. Soil Conserv Serv. Div. Sedimentation Studies SCS-SS-29. 1939.

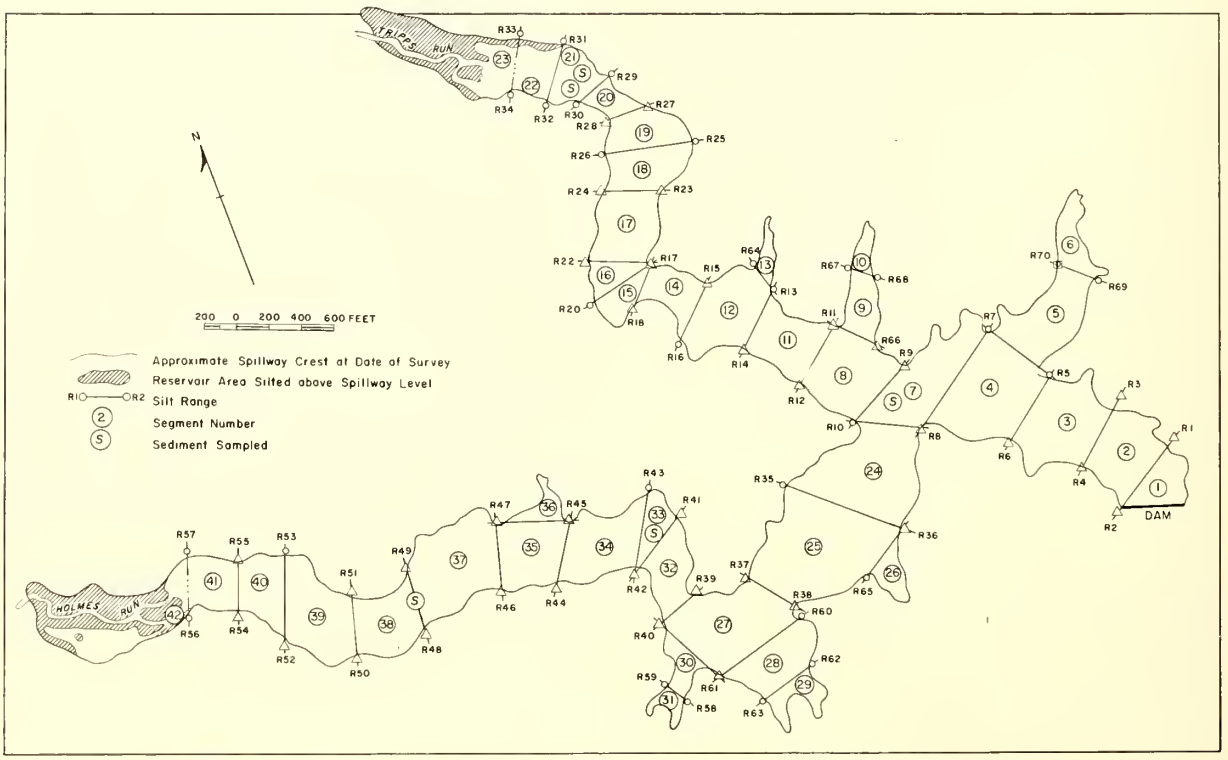

Figure 1.--Sediment and water-depth measurements made at close intervals along 41 cross-section ranges, Lake Barcroft (Holmes Run and Tripps Run), Fairfax County, Va.

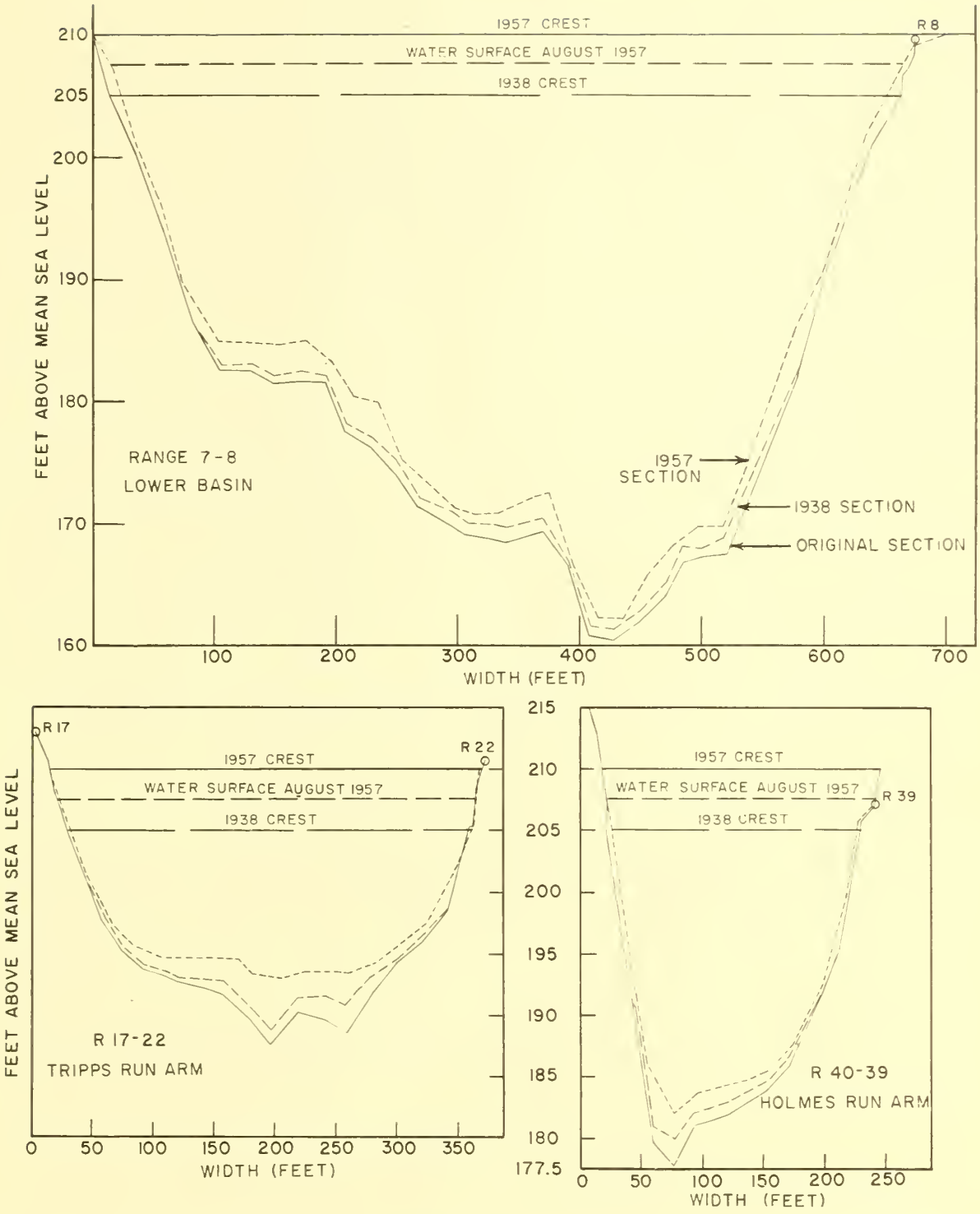

Figure 2.--Representative cross sections, Lake Barcroft, Fairfax County, Va.

SCS-34,
Jan. 1958

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

RESERVOIR SEDIMENTATION DATA SUMMARY

Lake Barcroft — NAME OF RESERVOIR

5-1 — DATA SHEET NO.

DAM

1. OWNER: Lake Barcroft Corp.	2. RIVER: Trib. of Potomac R.	3. STATE: Virginia
4. SEC. TWP. RANGE	5. NEAREST TOWN: Falls Church	6. COUNTY: Fairfax
7. STREAM BED ELEV.: 148 m.s.l.	8. TOP OF DAM ELEV.: 211	9. SPILLWAY CREST ELEV.: 210

RESERVOIR

10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. SURFACE AREA ACRES	13. STORAGE ACRE-FEET	14. ACCUMULATED ACRE-FEET	15. DATE STORAGE BEGAN
a. FLOOD CONTROL					Jan. 1915
b. POWER					
c. WATER SUPPLY (1938)	205	115.4	1,847	1,847	16. DATE NORMAL OPER. BEGAN
d. IRRIGATION					
e. CONSERVATION					
f. INACTIVE (1957)	210	128.6	2,092	2,092	

WATERSHED

17. LENGTH OF RESERVOIR: 1.4 MILES		AV. WIDTH OF RESERVOIR: 0.07 MILES	
18. TOTAL DRAINAGE AREA: 14.5 SQ. MI.		22. MEAN ANNUAL PRECIPITATION: 40 INCHES	
19. NET SEDIMENT CONTRIBUTING AREA: 14.3 SQ. MI.		23. MEAN ANNUAL RUNOFF: 17 INCHES	
20. LENGTH: 6.8 MILES	AV. WIDTH: 2.8 MILES	24. MEAN ANNUAL RUNOFF: 12,965 AC.-FT.	
21. MAX. ELEV.: ± 500	MIN. ELEV.: 148	25. CLIMATIC CLASSIFICATION: Humid	

SURVEY DATA

26. DATE OF SURVEY	27. PERIOD YEARS	28. ACCL. YEARS	29. TYPE OF SURVEY	30. NO. OF RANGES OR CONTOUR INT.	31. SURFACE AREA ACRES	32. CAPACITY ACRE-FEET	33. C/W RATIO AC.-FT. PER SQ. MI.
Jan. 1915	-	-	-	-	115.4	[1] 1,847 / 2,380	127
Feb. 1938	23.1	23.1	Range detailed	41	115.0	1,762	122
Aug. 1957	19.5	42.6	Range	41	128.6	2,092	144

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW ACRE-FEET			36. WATER INFL. TO DATE AC-FT.	
		a. MEAN ANNUAL	b. MAX. ANNUAL	c. PERIOD TOTAL	a. MEAN ANNUAL	b. TOTAL TO DATE

26. DATE OF SURVEY	37. PERIOD SEDIMENT DEPOSITS ACRE-FEET			38. TOTAL SED. DEPOSITS TO DATE ACRE-FEET.		
	a. PERIOD TOTAL	b. AV. ANNUAL	c. PER SQ. MI.-YEAR	a. TOTAL TO DATE	b. AV. ANNUAL	c. PER SQ. MI.-YEAR
Feb. 1938	85	3.68	0.257	85	3.68	0.257
Aug. 1957	203	10.41	.728	288	6.76	.473

26. DATE OF SURVEY	39. AV. DRY WGT. LBS. PER CU. FT.	40. SED. DEP. TONS PER SQ. MI.-YR.		41. STORAGE LOSS PCT.		42. SED. INFLOW PPM	
		a. PERIOD	b. TOTAL TO DATE	a. AV. ANNUAL	b. TOT. TO DATE	a. PERIOD	b. TOT. TO DATE
Feb. 1938	[2] 60	336	336	0.20	4.60		
Aug. 1957		950	618	[1] .38	[1] 12.1		

[1] Based on capacity of 210-foot crest elevation.
[2] Assumed.

Figure 3.--Reservoir sedimentation data summary.

from shore to shore over the range, and this was traversed by boat containing a fathometer and linemeter. Continuous water-depth measurements were recorded on a fathogram. Distances from shore were measured along the cable by means of the linemeter mounted in the boat, and distances recorded at 20-foot intervals by a "pip" on the fathometer charts. Where the range monuments were not found, the cable was stretched across the lake as near to the original range as could be determined by comparing the configurations of the shoreline with those shown on the 1938 map and the 1937 and 1953 aerial photographs of Lake Barcroft. About two-thirds of the original monuments could not be located because they were either submerged or obliterated by construction.

Five sediment samples were taken--2 in the Holmes Run arm of the lake, 2 in the Tripps Run arm, and 1 at the junction of the 2 arms. They were obtained with an 8-foot brass, piston-type sediment sampler.

Sedimentation in the Reservoir

Summary of data. --Figure 3 shows the rate of silting of Lake Barcroft together with other pertinent information for the two surveys. The sediment yield from the watershed from 1938 through 1957 was more than double that from 1915 through 1937 (fig. 4).

It appears that the amount of erosion and, therefore, the amount of sediment produced is influenced primarily by the quantity of land stripped of cover during construction (fig. 5, B). To anticipate future conditions, say in 1970, based on past figures and current trends, it is assumed that the present high rate of urbanization, which is almost 3 percent annually, will diminish in the ensuing 13 years since 67 percent of the watershed is already urban. If the average rate of urbanization until 1970 falls to 1.5 percent of the watershed annually by 1970 about 87 percent of the drainage area will be urban.

Continuing the same relationship between percent of area under construction and the annual capacity loss in acre-feet, this indicates a capacity loss of about 6.5 acre-feet annually, or 85 acre-feet between 1957 and 1970, making a total loss of about 375 acre-feet of capacity since 1915, or 15.8 percent. With construction almost completed, the rate of erosion may be expected to decrease to only slightly more than the moderate erosion rate before 1938 (fig. 5, A). which produced an annual average storage loss of 0.2 percent.

The length and area of the lake is decreasing, however, notably in the two end segments, because of delta building (figs. 1, 6). The upper reaches of the 2 arms are being transformed into swamps and marshes by accelerated sedimentation. The total capacity loss to the present level

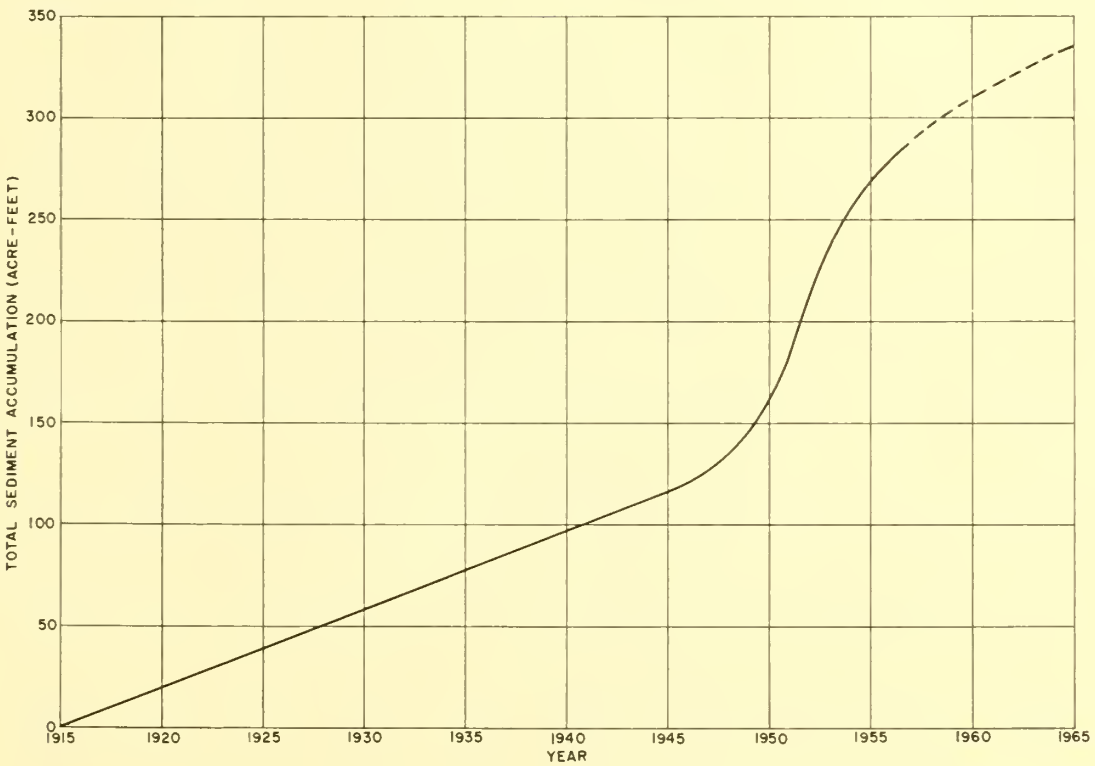

Figure 4.--Total sediment accumulation in Lake Barcroft, Fairfax County, Va., by year.

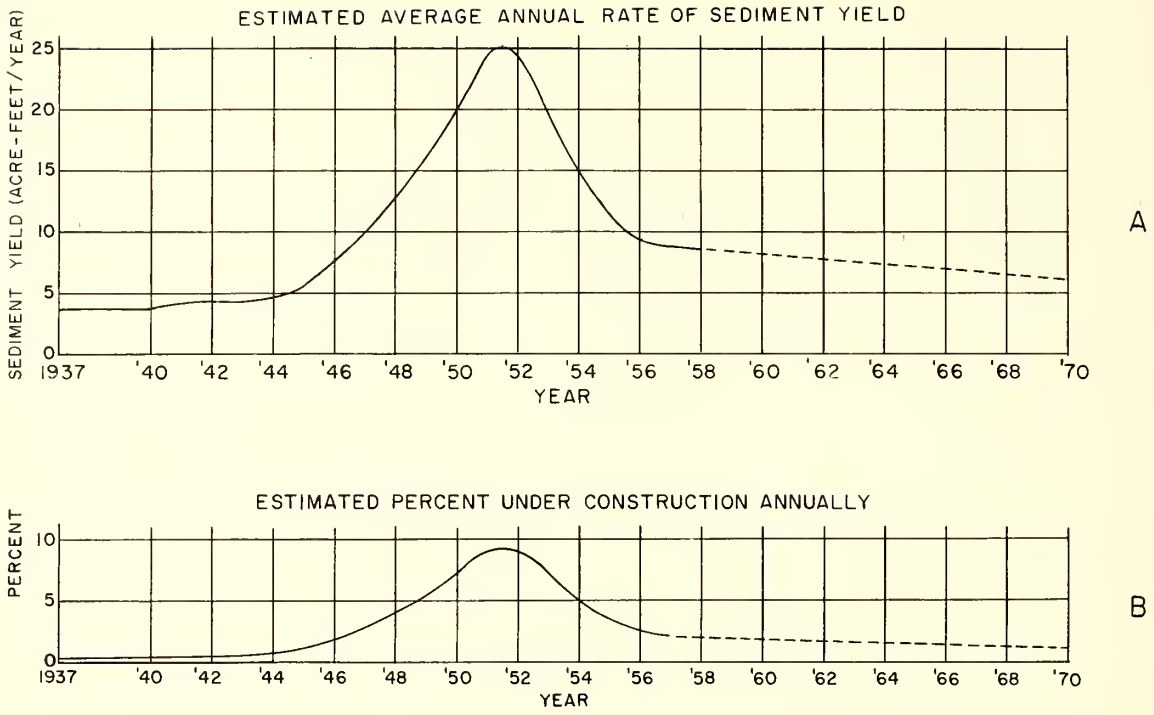

Figure 5.--Estimated average annual sediment yield; percent of watershed under construction, Lake Barcroft Watershed, Fairfax County, Va.

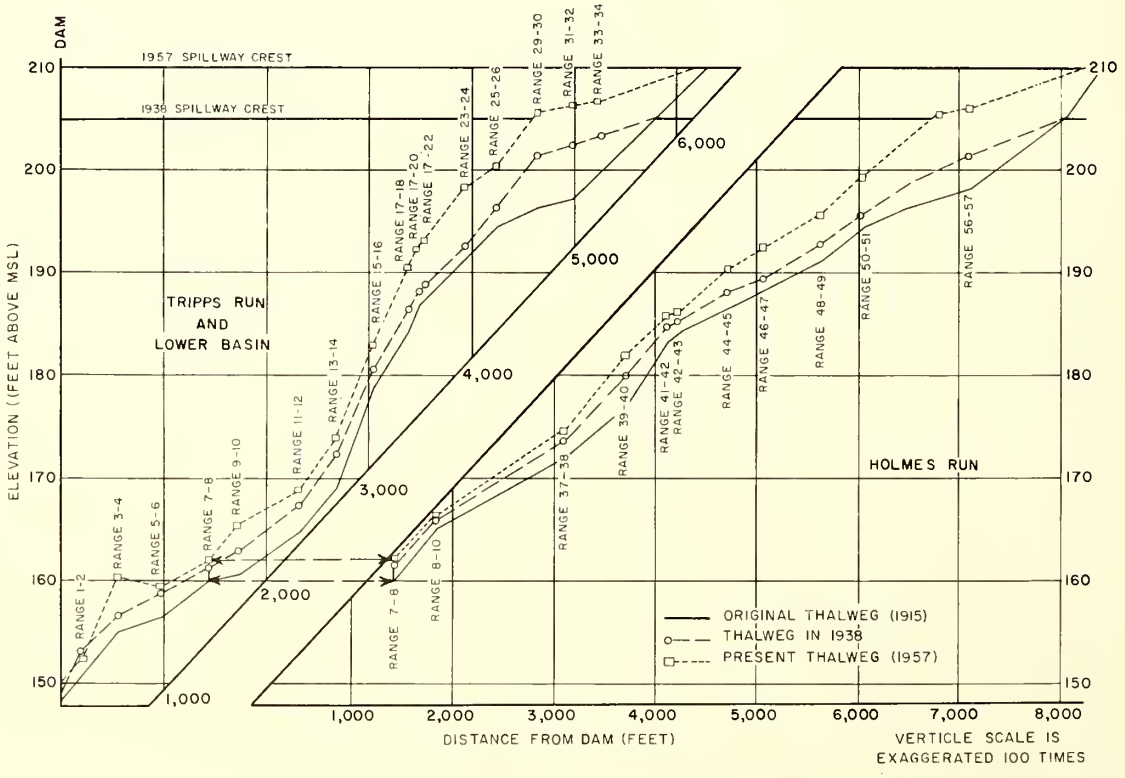

Figure 6.--Profile of Lake Barcroft, Fairfax County, Va.

is 12 percent. The current annual rate of capacity loss is almost 0.4 percent.

Character of sediment. --The sediment of Lake Barcroft consists mainly of silt and very fine sand with clay and some fine-to-medium sand. The proportion of sand increases toward the upper ends of the arms and the proportion of clay increases toward the dam. The deltas and lake sediments directly below the deltas consist of very fine sand and silt with a very small portion of clay. Some fine-to-medium sand has been deposited in or near the channel. In the lower half of the reservoir the sediment is essentially clay and fine silt with some coarser materials brought in by the side tributaries.

All of the sediment contains mica flakes derived from the schists in the watershed. The amount and size of mica flakes also decreases toward the dam. Where these small yellowish flakes are concentrated, as they are in some layers, they cause the sediment to appear sandy.

When first removed from the reservoir the sediment samples appear blue or blue-gray with streaks of brown or yellow. After exposure to air and drying, the color changes to yellow or red and buff, due to the presence of iron oxides.

Organic matter is common throughout the reservoir, bits of stems and leaves being buried in the sediment as it accumulates.

Distribution of sediment. --The rates of sediment production from the drainage areas of Tripps Run and Holmes Run are essentially the same, being 0.43 acre-foot per square mile annually for Tripps Run drainage area and 0.44 acre-foot per square mile for Holmes Run. This has resulted in a total capacity loss of 17.6 percent in the Tripps Run arm, 13.7 percent in the Holmes Run arm, and 5.7 percent in the lower basin of the lake (table 1). Only near the headwaters of Tripps Run, on range 29 to 30, is the average sediment thickness (determined by dividing the cross-sectional area of sediment in square feet by the width of the lake) greater than 5 feet. As might be expected the deltas in both Holmes Run and Tripps Run are enlarging, and vegetation that has developed in these shallow zones tends to slow down and trap more sediment in these two end segments.

Examples of the lateral distribution of sediment throughout the reservoir are shown in the cross sections in figure 2 and indicate the thickness of sediment increases toward the channel.

Compaction of sediment. --Five sediment samples were taken from Lake Barcroft for volume-weight determinations. These weights ranged from a maximum of 60.4 pounds per cubic foot dry weight in the upper end of the reservoir where silts and very fine sands predominate to a minimum of 33.8 pounds per cubic foot dry weight in the lower lake where clay predominates. The average dry weight of all samples was 49 pounds per cubic foot. Sediment density increases with depth because the lower sediment, having been deposited first, has had more time to compact. The weight of overlying sediment also aids in compaction of lower sediments.

Table 1.--Distribution of sediment in Lake Barcroft

Section	Original capacity at 205-foot spillway level	Original capacity at 210-foot level	1957 sediment volume	1957 capacity loss	1957 surface area	Average sediment thickness
	Acre-feet	*Acre-feet*	*Acre-feet*	*Percent*	*Acres*	*Feet*
Tripps Run arm.....	429	573	101	17.6	30.7	2.61
Holmes Run arm.....	820	1,053	144	13.7	64.7	2.32
Lower Basin.....	598	753	43	5.7	33.2	1.12
Total reservoir....	1,847	2,380	288	12.0	128.6	2.01

The Watershed

Drainage area. --The watershed of Holmes Run and its principal tributary, Tripps Run, extends over an area of 14.5 square miles as determined in 1938 and as planimetered from the Fairfax County, Va., aerial photographs.[3] Holmes Run drains an area of 7.6 square miles, Tripps Run an area of 5.5 square miles, and 1.4 square miles drain directly into the lower basin of the reservoir.

Geology[4]. --The drainage area of Lake Barcroft lies in the Piedmont Plateau just west of the Fall Line which separates it from the lower lying Coastal Plain. About one-third of the area, mainly in the headwaters, is underlain by the Wissahickon schist, a pre-Cambrian formation consisting of chlorite-muscovite schist and some thin layers of quartzite. The lower two-thirds of the drainage basin is underlain by pre-Cambrian granites, gneisses, and diorites. A few small areas of unconsolidated marine deposits of sand, gravel, and clay,

[3] Taken by Assoc. Aerial Survey Co., scale 1/12,000, March 1957.

[4] See footnote 2.

Cretaceous and younger in age, extend into the area near the lake and also occur in the extreme headwaters.

A soil mantle several feet thick generally covers the pre-Cambrian formations. Bedrock is exposed only on the steeper slopes chiefly near the lake.

Topography and drainage[5]. --The topography of this area is moderately rolling to hilly, although considerable areas of undulating to gently rolling topography occur on the main divides. The average relief is about 100 feet; elevations range from about 200 feet at the lake to nearly 500 feet on the headwater divide.

The drainage system is typically dendritic (fig. 7). The valleys are rather narrow and gorgelike near the lake, becoming shallower and somewhat wider headward.

Soils. --The soil types and their relative extent in the drainage area, as shown on the soil map of Fairfax County, follow:

	Percent
Glenelg silt loam	53.6
Manor silt loam	18.9
Chewacla silt loam Wehadkee silt loam Mixed alluvial land	8.9
Hilly land, loamy and gravelly sediment	6.7
Beltsville silt loam	5.3
Beltsville loam	2.9
Fairfax loam	1.9
Elioak silt loam	1.8
Total	100.0

The Glenelg, Manor, and Elioak soils are developed on the crystalline rocks of the Piedmont, and the Beltsville and Fairfax soils in this area are on remnants of the Coastal Plain sediments within the Piedmont.

The Glenelg silt loam, derived from gneiss, schist, and granite, is a brown, friable, well-drained soil. It is low to fair in organic matter and natural fertility and has good water-holding capacity. It is strongly acid in most places (pH 5.0-5.5), is easy to work and conserve, and is one of the most productive soils in the county. This soil has weathered deeply; the parent rock is exposed only rarely on the steepest slopes. It lies on gently to strongly rolling topography and on the steeper slopes is subject to severe erosion when not protected by growing crops or other vegetation.

The Manor silt loam, derived from sericitic schist, is a soft, porous, highly micaceous, weakly developed soil. It is associated with the Glenelg and Elioak soils of the Piedmont uplands and has very little subsoil development in most places. It is excessively drained and has a low water-holding capacity and natural fertility. The soil is shallow over deeply weathered parent rock. This soil is excellent for septic tank drainage fields.

[5] See footnote 2.

The Wehadkee silt loam is poorly drained and occurs in association with the somewhat poorly drained Chewacla silt loam. The mixed alluvial land, which has variable drainage and texture characteristics, is associated with both the Wehadkee and Chewacla soils. They consist of soil material that has washed from the soils of the Piedmont uplands. These soils all occur in the flood plains of Tripps Run and Holmes Run. They are subject to flooding and are best adapted to permanent pasture or parks.

The Hilly land, loamy and gravelly sediment is a shallow to moderately deep, highly variable, light colored soil of the high-lying Coastal Plain terraces and is derived from unconsolidated marine sediment. It contains round waterworn gravel and cobbles and is underlain by beds of gravel, sand, silt, and clay (pH 4.5-5.5).

The Beltsville silt loam is formed on high-lying marine terraces. It is light colored and moderately well drained. It has a grayish-brown to yellowish-brown surface soil about 7 inches thick, a strong-brown silty clay loam subsoil, and a hardpan between 16 and 24 inches beneath the surface. Surface runoff is medium to slow and internal drainage is very slow. It is strongly acid (pH 4.5-5.5) and is best suited for small grain and mixed hays.

The remaining soils in the watershed--the Beltsville loam, Fairfax loam, and Elioak silt loam--are of limited extent and, therefore, of minor importance.

Erosion. --It appears that sheet erosion on agricultural land in the watershed is taking place at only a moderate rate and gullies are practically nonexistent. Rills and sheet erosion, however, are greatly increased where the cover and topsoil are stripped from areas of construction during urbanization.

This increased erosion of denuded sites generally lasts from 3 months to a year as the land is being converted from pasture, woodland, or idle land or to highways, residential, business, or other urban uses. After lawns are established and streets, parking lots, and walks are laid, the sheet-erosion rate should return to about its former moderate rate from good pastureland although the runoff will increase because of roofs, streets, and sidewalks. This, in turn, will tend to increase roadside, stream channel, and bank erosion. The delivery rate of sediment to the lake will then be somewhat higher than originally unless corrective measures (vegetated and lined channels, streambank-protection measures) are installed.

Erosion from cultivated land in the watershed is no longer significant since such land now makes up only about 0.5 percent of the watershed and consists mostly of nurseries and gardens on the more gently sloping lands where accelerated erosion is least likely to occur. One-fourth of the watershed remains in woodland that still provides good cover against erosion.

Land use. --The following approximate figures on land use in the Lake Barcroft watershed were obtained by measurement from aerial photographs

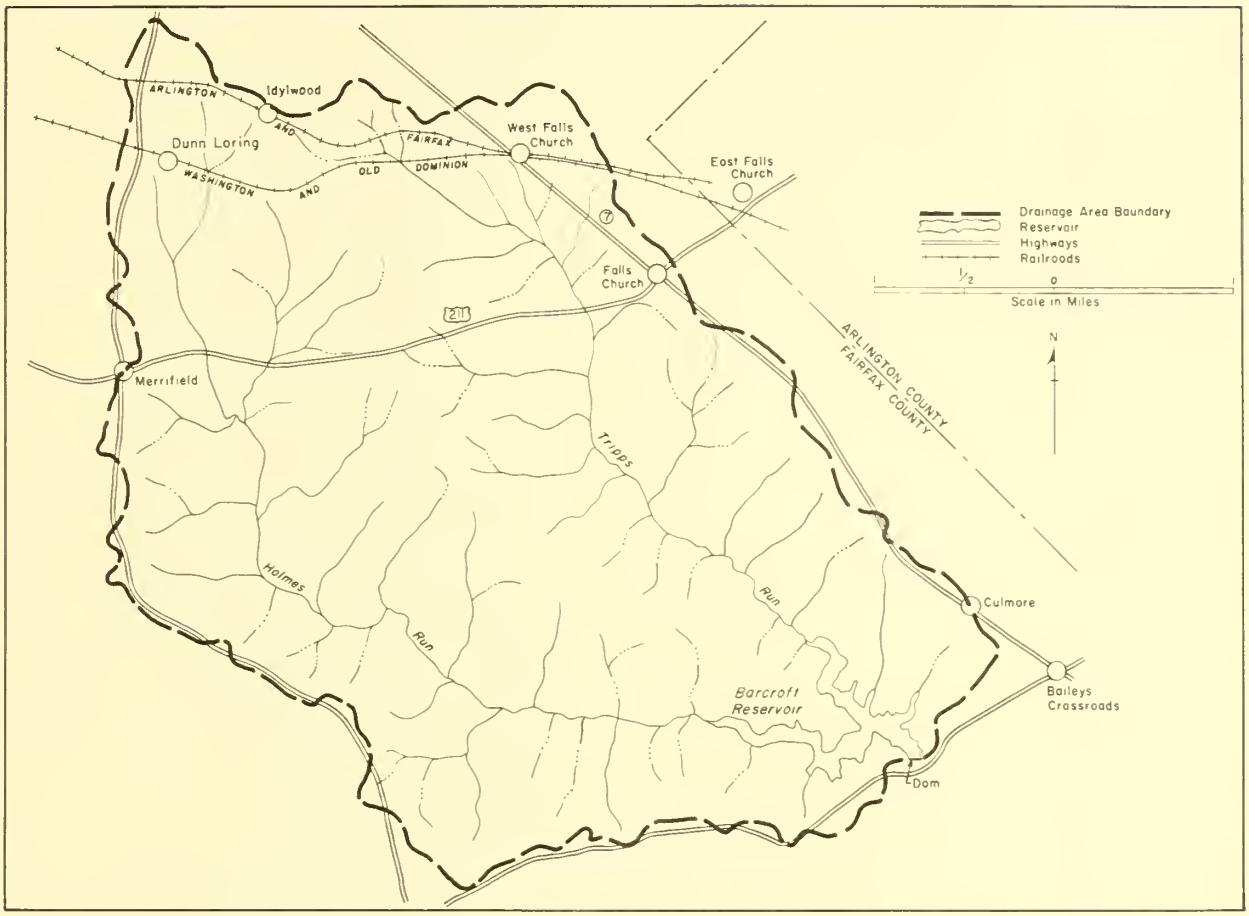

Figure 7.--Lake Barcroft and drainage area, Fairfax County, Va.

made in 1937, 1953, and 1957. A reconnaissance of the drainage area was made in both February 1938 and November 1957 to verify land use as to those dates.

	Watershed area		
	1937	1953	1957
	Percent	*Percent*	*Percent*
Cultivated	18	0.7	0.5
Pasture (and idle)	23.5	6.4	5.6
Woodland	53	32.3	25.6
Residential (and other urban)	5.5	60.6	68.3
Total	100.0	100.0	100.0

Following World War II the population of this area of Fairfax County, Va., began to expand rapidly. Much of the land formerly used for pasture and woodland was converted to urban use such as homesites, shopping centers, streets, and roads (fig. 8). The average rate of conversion of land from agricultural to urban use from 1937 to 1957 was about 3 percent annually. Actually, most of this change took place in the 10 years, 1947-57. Analysis of relationship betweer population growth and land use conversion indicates that the peak rate occurred during the years 1951 and 1952 when the average annual rate approximated 9-percent conversion per year. In 1957 the rate of conversion was about 2.5 percent; only about 32 percent of the watershed remained to be urbanized. At the present rate of construction, complete urbanization would be achieved by 1970.

Normal annual rainfall. --From a 30-year record (1921-50) at the Washington National Airport Weather Bureau office, which is about 4 miles east of Lake Barcroft, the normal annual precipitation is 40.48 inches. The monthly normal precipitation ranges from 2.44 inches in February to 4.75 inches in August.

Mean annual runoff. --From records kept of the Accotink Creek in Fairfax County, Va., near Annandale, from 1948 to 1953, and Accotink Station, 1949-53, with drainage areas of 23.6 square miles and 37.0 square miles, respectively, the mean annual runoff is about 17 inches[6], or 907

[6] U. S. Geological Survey. Surface Water Supply of the United States, 1953. U. S. Geol. Survey Water-Supply Paper 1272, pp. 478-479. 1956.

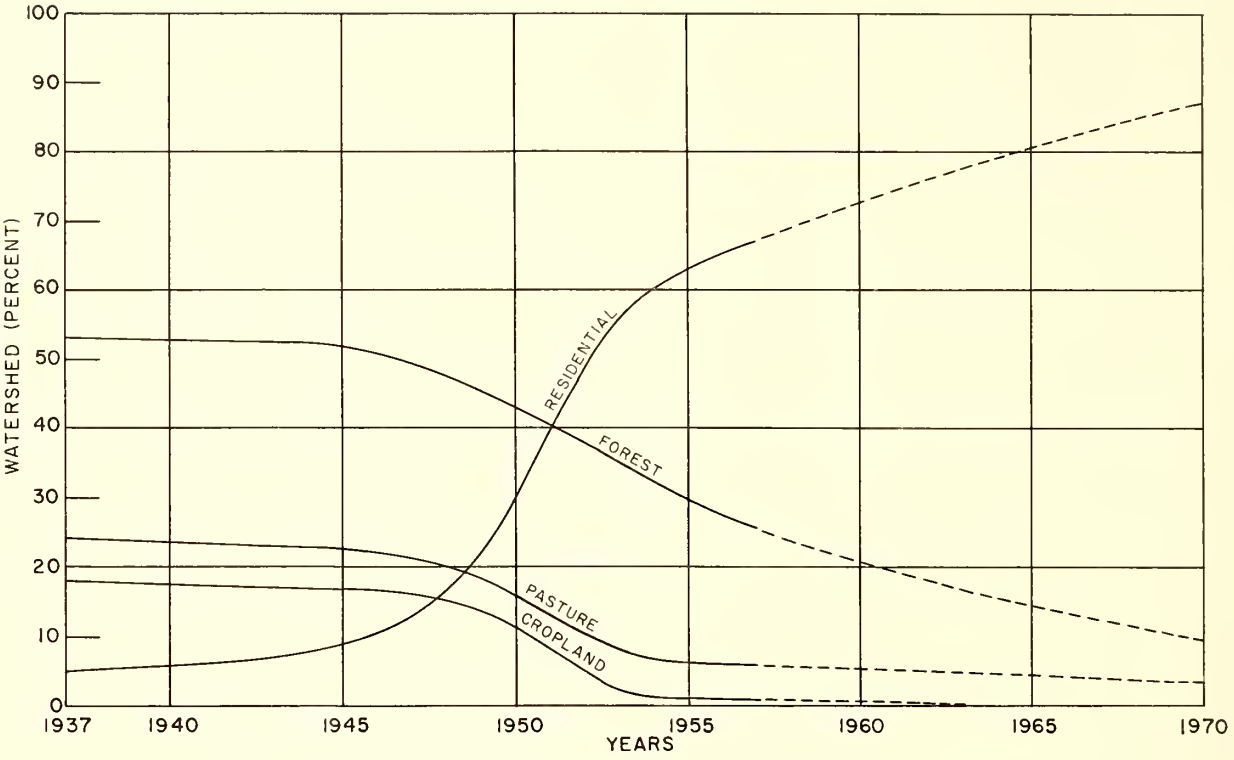

Figure 8.--Land use changes of Lake Barcroft Watershed, Fairfax County, Va.

acre-feet per square mile. This area is about 5 miles south of Lake Barcroft, and these figures are used as being applicable to the Lake Barcroft watershed. This would indicate that the mean annual inflow to Lake Barcroft is 12,965 acre-feet or 4.2 billion gallons.

Sources of Sediment

Before 1942, the principal source of sediment delivered to Lake Barcroft was from sheet erosion on scattered areas of cultivated land. These occupied about 18 percent of the watershed area. A secondary source was the idle and pasture land of the watershed. Though eroding at a lesser rate than cultivated land, it nevertheless became an important source because such land extended over about one-fourth of the watershed area. Roadside erosion of Federal, State, and county roads and erosion of streambanks provided a small part of the sediment.

The woodland area, which occupied 53 percent of the watershed area, provided protective cover against erosion and only minor amounts of sediment were derived from this land. Actually the watershed was in excellent condition for erosion prevention, and the rate of sediment production was less than 70 percent of what might be expected from a Piedmont area as indicated by measurements of sediment yields from nearby watersheds.

The influx of population to Fairfax County, and particularly to the eastern part where the watershed lies, began in 1942. Conversion of land use from agricultural to urban started at that time and reached its peak in 1951-52. By 1957, three-fourths of the pasture and idle land and one-half of the woodland had been converted to urban land. Urban land, particularly well-kept lawns, provides protection against sheet erosion, and, of course, pavement and roofs in themselves stop erosion entirely. On the other hand, flash runoff from pavement and roofs concentrates flows which accelerate channel erosion such as roadside-ditch and stream-channel erosion unless adequate protective measures are provided.

The greatest effect of urbanization on erosion occurs during and immediately following conversion. The removal of trees, brush, and topsoil exposes the soil to detachment by raindrop impact. Normally such soil remains bare for about 3 months for a single dwelling construction. Large housing and apartment developments may expose unprotected soil for a year or more. A major construction project may expose soil to accelerated erosion for 2 or 3 years.

It has been calculated that a single rainstorm of 1 inch occurring for 30 minutes on an exposed soil with a 10-percent slope would erode soil at the rate of 23 tons per acre as compared to a rate of 1-1/3 tons under natural conditions. Such rains and slope conditions are not unusual in the

watershed. In fact, a rain 1 inch or more in 30 minutes occurs twice a year on the average.

The greatly increased rate of sedimentation in Lake Barcroft is due primarily to the construction associated with conversion of agricultural land to urban. The increase of sediment production from an average of about 1/4 acre-foot per square mile of drainage area per year before 1938 to a rate of about 3/4 acre-foot per square mile annually from 1938 to 1957 is indicative of the influence of clearing sites of vegetation and topsoil during construction. It is anticipated that the rate of silting will decrease progressively until it levels off to minimum rate by about 1970, when the watershed will be almost completely urbanized. It is doubtful that it will ever drop to a rate as low as that prevailing before 1938, unless adequate measures are installed to reduce roadside-ditch and stream-channel erosion due to flash runoff from pavement and roofs.

Future erosion. --The sediment production from this watershed is expected to continue at a rate considerably above the rate before 1938 as urbanization progresses during the next decade or two. The proposed Washington Circumferential Freeway is to cross the watershed in the Holmes Run valley east of Dunn Loring and Merrifield. Homes and streets will be constructed on currently undeveloped land. For example, several blocks of woodland in the watershed will be converted into a residential area in this period.

On the other hand, in the areas where construction is completed and soil is no longer exposed, the sheet-erosion rate should diminish to about the same rate as that from good pastureland. Control of increased runoff from roofs and pavement with storm sewers, vegetated and lined channels, and streambank-protection measures should prevent any significant increase of roadside, stream-channel, and bank erosion.

The Community

The community of Lake Barcroft Shores comprises about 1,000 homesites. About 700 houses have now been constructed in the area. The plans for each house in the community are approved by authorities before construction to assure that minimum requirements of the community have been met. Nonspeculative property owners attempt to maintain the area in its original woodland condition. The lake, of course, is the focal point, and the desirability of the area as a homesite is amplified by the absence of fresh-water lakes in the vicinity of Washington, D. C. Five swimming beaches have been developed on the lake for use of the property owners.

Residents in the headwater areas of the lake have, in the space of 2 to 3 years, witnessed the migration of delta areas down into the lake in both the Holmes Run and Tripps Run arms. As mentioned previously, the surface-water area of the lake has been decreased by 6 acres since the dam was raised in 1942. In only 3 years the swimming beach in the upper part of the Tripps Run arm has become practically useless. Sediment is encroaching on the 2 community beaches on Holmes Run and on private beaches and shorelines in both arms.

Evaluation of Remedial Measures

General. --The reduction of sedimentation to a reservoir may be accomplished: (1) By reduction of sediment movement out of the watershed, (2) by venting sediment through the dam, and (3) by removal of deposited sediment from the reservoir. The selection of any feasible method or methods for a specific reservoir or lake is determined by the physical and economic factors involved. Following is a brief discussion of each method and its limitations as applied to Lake Barcroft:

Reduction of sediment movement out of the watershed. --Reduction of sediment movement out of a watershed may be achieved by installing land-treatment measures on agricultural land to prevent erosion. Agricultural land-treatment measures include conversion of land use that is conducive to erosion to a use that protects it from erosion. Improvement in management and in cropping practices, such as contour tillage and stripcropping, and such structures as terraces, diversions, and grass waterways will effect substantial reductions in sediment yields.

Engineering structures such as upstream impounding dams and sedimentation basins provide an effective method of reducing downstream damages.

Neither agricultural land treatment nor structural measures in upstream areas of the watershed will provide a practical solution to the problem of reducing movement of sediment out of the Lake Barcroft watershed into the lake. The many thousands of landowners in the watershed, the rapidly changing myriad of sediment-source areas, and the lack of widespread areas of agricultural land preclude the adoption of this method for effective control.

Upstream structural measures in the watershed, such as sedimentation basins are impractical because of lack of sites for adequate sediment storage and high land values which would create an extremely high cost of control.

To reduce sediment movement and pollution by legal action, the Board of Supervisors of Fairfax County, on December 21, 1955, passed an ordinance making it unlawful to cause or allow the discharge of dirt, soil, or other pollutants into any State waters in the county by storm or floodwater. Violation of the ordinance is punishable by a fine not to exceed $300 or 30 days in jail; with each day's violation of the ordinance constituting a separate offense.

Contractors have been encouraged to provide in their construction program for the paving of roads and sodding at early dates. The Soil Con-

servation Service, through the Work Unit Office at Fairfax, Va., has provided technical assistance to contractors in an effort to reduce erosion from construction.

Although these efforts are highly commendable, they have not been fully effective in reducing sediment movement out of the watershed.

Venting sediment through dam. --Under certain topographic conditions, character of sediment, and movement of water through impounding reservoirs (density flows), reduction of silting of reservoirs may be achieved by the proper placement of outlets in the dam. Although seldom fully effective for venting all sediment, under certain favorable conditions a sizable part of sediment can be flushed from reservoirs. But these conditions do not prevail at Lake Barcroft. The character of sediment is such that the maximum deposition occurs in the headwater areas, and only small parts of the total sediment inflow are transported to the dam where venting would be possible.

Removal of sediment from the reservoir. --Removal of sediment from reservoirs may be accomplished by hydraulic or mechanical methods. Normally removal of sediment is more costly and less effective over a long period than other remedial methods. The disposal of materials also presents problems that are difficult to solve. Pumping over the dam, for example, creates additional downstream problems such as deposition in navigable channels.

The cost of sediment removal is difficult to evaluate. It depends on the type of equipment used and the means of disposal. If the sediment must be trucked away, for example, the unit cost is much higher than if disposal can be made adjacent to the reservoir.

For Lake Barcroft, however, removal by dredging is the only positive and practicable method now available to satisfactorily restore the reservoir. But it is not economically feasible to remove sediment from the entire basin. However, the capacity loss in the lower lake will not be apparent for many years.

Conclusions

The conversion of formerly agricultural land in the watershed above Lake Barcroft to urban use has greatly accelerated erosion and the movement of sediment into Lake Barcroft. It is expected that this accelerated rate will continue for the next decade, or until construction activities cease in the watershed.

An ordinance to prohibit contribution of dirt, soil, and other pollutants to State waters has not been completely effective in reducing the accelerated rate of sedimentation in Lake Barcroft. More positive methods must be developed if reduction in damages is to be realized. In developing such methods the following measures would be most effective:

1. Removal of sediment and construction of sediment-collecting basins in the delta areas of Holmes Run and Tripps Run.
2. Continuation of efforts to minimize erosion and sediment production during construction.
3. Continuation of County Ordinance on Pollution of State Waters.
4. Stabilization of highway, road, and street drainage ditches.
5. Stabilization of stream channels.

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